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ABSTRACT

The objectives of this project were (1) to determine whether or not adapting instruction to student characteristics will improve the effectiveness and efficiency of training, (2) to identify the learner attributes that interact best with specific instructional treatments, and (3) to establish what must be done to create and implement a useful adaptive instructional system. The professional literature concerning adaptive teaching systems was reviewed and evaluated, and several approaches to accommodating instruction to student characteristics were identified and considered. Little empirical evidence was obtained to support the aptitude-treatment-interaction (ATI) approach, and the experimental evaluation of several alternative approaches to adaptive instruction was recommended. (Author/JEG)

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ACCOMMODATING INSTRUCTION TO STUDENT CHARACTERISTICS: TRENDS AND ISSUES

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The relevant professional literature concerning adaptive teaching systems was reviewed. Several alternative approaches to accommodating instruction to student characteristics were identified and discussed. Several recommendations were made regarding what additional research and development efforts are needed to ensure the successful implementation of adaptive instructional strategies in Navy training.

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FOREWORD

This study was conducted in response to Navy Decision Coordinating Paper, Education and Training Development (NDCP-Z0108-PN), under subproject PN.30A, Adaptive Experimental Approach to Instructional Design, and under the sponsorship of the Director, Naval Education and Training (OP-99). The overall objective of the subproject is to develop an empirically based instructional design support system to aid developers in deciding on instructional alternatives based on costs, benefits, and specific resource limitations. The specific objective of this effort was to identify measures of student characteristics that may be useful for indicating instructional treatments to be assigned to different individuals to maximize their attainment of specified educational outcomes. This endeavor (1) reviews the pertinent professional literature, (2) provides a summary of the problem and the state-of-the-art, (3) develops a rationale for conducting empirical studies, and (4) identifies research needed to improve individualized Navy training and education.

The results of this study are intended for use by the Navy's Instructional Program Development Centers, Chief of Naval Technical Training, Chief of Naval Education and Training, and the Defense Training research and development community.

DONALD F. PARKER
Commanding Officer

SUMMARY

Problem

The Navy has adopted computer-managed, individualized instruction for much of its technical training. This innovative technology makes it possible to increase the efficiency and effectiveness of such training by permitting each student's progress to be (1) more closely monitored, and (2) considered in the design of subsequent instruction.

Several researchers have speculated that the next logical step in the evolution of individualized training is to adapt instruction--by selecting specific instructional treatments--to individual characteritstics. Before doing so, however, investigators must decide what theoretical framework can be adopted as a basis for conducting further research and development efforts to produce a successful adaptive instructional system for Navy training.

Objective

The objectives of this effort were (1) to determine whether or not adapting instruction to student characteristics will improve the effectiveness and efficiency of training, (2) to identify the learner attributes that interact best with specific instructional treatments, and (3) to establish what must be done to create and implement a useful adaptive instructional system.

Approach

The professional literature concerning adaptive teaching systems was reviewed and evaluated, and several approaches to accommodating instruction to student characteristics were identified and considered.

Findings

1. Little empirical evidence has been obtained to support the aptitude-treatment-interaction (ATI) approach, which emphasizes the identification of aptitude measures that are useful for selecting instructional treatments to maximize individuals' attainment of educational objectives. Research results only partially support the hypothesis that customary psychometric (or personological) measures of ability, aptitude, and achievement are useful for selecting from among alternative instructional treatments; and the ATI literature is plagued by inconsistencies that preclude appropriate extrapolations. If there is a trend in the literature, it would seem to be simply that the results of ATI studies are incompatible. Very few ATIs have been substantiated to the extent that they can be used unequivocally as prescriptions for accommodating instruction to student characteristics.

2. The ATI approach's lack of success is due, in part, to the following reasons:

a. Methodological problems abound in the reported ATI research: (1) instructional treatments have traditionally consisted of complex or

uncontrolled manipulations that affect learner performance, (2) it has been difficult to distinguish among alternative teaching treatments, and (3) some aptitude and ability measures that have been used are too general and correlated to produce significant ATI effects.

b. Certain conceptual difficulties have afflicted numerous ATI investigations: (1) individual difference variables and alternative teaching treatments have seldom been carefully conceived, (2) the instructional treatments employed have differed only slightly, and (3) different abilities have been demanded by the task at various points in the training sequence.

c. Traditional ability and aptitude measures that have been derived psychometrically for selection purposes are irrelevant to learning and performance. Many tests of general ability and aptitude are neither useful indices of the student characteristics that are likely to interact with alternative instructional treatments nor capable of distinguishing among different styles of learning.

Conclusions

1. Cognitive processes could be regarded as individual difference variables for use in adaptive instruction. However, a dilemma that must be resolved is whether it is better to assign instructional treatments to capitalize on potent cognitive processes, or to assign instructional treatments to improve upon impotent ones.

2. The operations that students perform during the different stages of cognition (e.g., selecting, encoding, organizing, storing, retrieving, decoding, and generating information) are potentially profitable areas of study in the design and development of adaptive instructional systems.

3. Within-task measures of student behavior and performance during instruction (e.g., number of errors, response latencies, emotive states) are potentially useful for adaptive teaching purposes.

4. In adapting instruction to individual differences, it may be better to assume that dynamic, state, personological variables are more useful for predicting performance than are stable, trait, aptitude measures.

5. Incentive techniques, contingency-management procedures, and other motivational schemes need to be evaluated to assess the feasibility of their use in an accommodative manner.

6. Information-feedback procedures need to be evaluated on the basis of their suitability for specific students, subject matters, and tasks.

7. Instructional treatments can be accommodated to a learner's preferred mode of information processing as specified by computer-based electrophysiological indices.

Recommendations

To maximize the cost-effectiveness of Navy technical training, several alternative approaches to adaptive instruction should be experimentally evaluated:

1. Analyze and assess individual differences in acquiring, retaining, and retrieving knowledge.

2. Adapt instructional treatments to a student's cognitive style or predominant mode of information processing.

3. Design and develop adaptive instructional systems around the relevant cognitive processes.

4. Accommodate instruction to students, using (a) micro treatments based upon within-task measures taken during the course of learning, and (b) macro treatments based upon pretask measures.

5. Design and evaluate an adaptive instructional system in which students select and control the instructional treatments that they feel are most appropriate to their needs.

6. Identify and assess adaptive incentive techniques that can be accommodated to individual students to enhance their learning and performance.

7. Select and evaluate information feedback procedures on the basis of their suitability for specific students, subject matters, and tasks.

8. Determine the feasibility of using psychophysiological correlates of cognitive processing, such as lateral hemispheric specialization, to suggest adaptive instructional strategies.

CONTENTS

	Page
INTRODUCTION	1
Problem	1
Objectives and Approach	1
APTITUDE-TREATMENT-INTERACTION (ATI)	3
Overview	3
Reasons for ATI's Lack of Success	6
Methodological Problems	6
Conceptual Difficulties	8
Irrelevant Mental Abilities and Aptitudes	10
ALTERNATIVE APPROACHES TO ADAPTIVE INSTRUCTION	13
Relevant Cognitive Processes	13
Cognitive Processes as Individual Differences	14
Cognitive Styles	16
Within-task Measures	21
Learner Control and Dynamic Characteristics	21
Adaptive Incentive and Feedback Techniques	23
Psychophysiological Procedures	24
CONCLUSIONS	27
RECOMMENDATIONS	29
REFERENCES	31
REFERENCE NOTES	41
DISTRIBUTION LIST	43

INTRODUCTION

Problem

The increased utilization of computer-managed, individualized instruction for Navy technical training has increased the efficiency and effectiveness of such training by permitting each student's progress to be (1) more closely monitored and (2) considered in the design of subsequent instruction. Several researchers have speculated that the next logical step in the evolution of individualized training is to adapt instruction--by selecting specific instructional treatments--to individual characteristics. Before doing so, however, investigators must decide what theoretical framework can be adopted as a basis for conducting further research and development efforts to produce a successful adaptive instructional system for Navy training.

Objectives and Approach

The objectives of this effort were (1) to determine whether or not adapting instruction to student characteristics will improve the effectiveness and efficiency training, (2) to identify the learner attributes that interact best with specific instructional treatments, and (3) to establish what must be done to create and implement a useful adaptive instructional system.

The literature concerning adaptive teaching systems was reviewed and evaluated, and several approaches to accommodating instruction to student characteristics were studied.

APTITUDE-TREATMENT-INTERACTION (ATI)

Overview

Several psychologists (e.g., Bracht, 1970; Cronbach, 1957, 1967; Cronbach & Gleser, 1965; Cronback & Snow, 1969; Gagne', 1967; Glaser, 1967, 1972, 1977; Jensen, 1967, 1968) have asserted that no single teaching method is best for all students. If this is true, then students will be able to reach educational goals more efficiently when instructional procedures are adapted to individual differences. This would be possible if instructional treatments were accommodated to premeasured student aptitudes. According to Cronbach (1957, p. 681), it is best to "design treatments not to fit the average person, but to fit groups of students with particular aptitude patterns," or conversely, to "seek out aptitudes which correspond to (interact with) modifiable aspects of the treatment." In this context, aptitude is "any characteristic of the individual that increases (or impairs) his probability of success in a given treatment"; and treatment, "variations in the pace or style of instruction" (Cronbach & Snow, 1969, p. 7). Aptitude includes any index of individual difference that distinguishes among students and treatments with respect to learning outcomes. It does not refer to general and mental ability (Snow & Salomon, 1968). As used in the literature, though, aptitude does indicate a rather enduring trait from which extrapolations are made concering appropriate teaching treatments (Cronbach & Snow, 1969). However unintentional, this trait aspect of aptitude connotes a tendency that is relatively stable over short intervals (Tobias, 1976).

Cronbach (1967) discussed three models for accommodating instruction to specific students. The first involved simply manipulating the pace of teaching; the second, tracking homogenous types of students who were given general treatments derived from instructional macro-theories (i.e., those entailing decision rules that prescribe feedback, prompting, reinforcement, etc.); and the third, designing instructional treatments as a function of how students normally acquire and manipulate material. The latter of these is much more accommodating in that it permits the modification of not only teaching treatments, but also student cognitive aptitudes. For the most part, Cronbach's models stressed pretask instructional adaptation (Tennyson, 1975); that is, they presumed that instructional treatments can be determined from empirically established aptitude measurements taken before the actual learning situation, and that regression equations can be derived for assigning certain types of students to specific instructional treatments.

Aptitude measurements can be used for adapting instructional treatments to student characteristics only if aptitudes and treatments interact (Cronbach, 1967; Cronbach & Gleser, 1965; Cronbach & Snow, 1969, 1977); that is, aptitude measures must be developed to predict which individuals will learn best from specific instructional treatments. If such measures are available, then teaching treatments can be prescribed for types of students having specific aptitude profiles. This can be facilitated by the ability to discriminate among instructional treatments to maximize their interactions with aptitude measures. Cronbach (1967) proposed a comprehensive

program of research to identify aptitudes that interact best with specific treatments. This area of research has been labelled aptitude-treatment-interaction, or ATI. The emphasis of ATI research is on identifying the aptitude measures that are useful for selecting instructional treatments to maximize individual attainment of specified educational objectives (Glaser, 1972).

Supporting evidence is obtained when significant interactions are established between alternative instructional treatments and individual differences, or personological variables. In ATI research, the personological variable is defined as any measure of individual characteristics (e.g., IQ, scientific interest, aptitude, anxiety) (Bracht, 1970). ATIs are usually sought in educational research by employing two-by-two factorial analysis of variance (ANOVA) experimental designs. It is hoped that one personological variable correlates significantly with learning performance under one instructional treatment, and the other personological variable correlates significantly with learning performance under the other instructional treatment.

> An ATI exists, in effect, when the regression of outcome under treatment A, upon certain pretreatment information [e.g., aptitude measures], differs in slope from the regression for the same variables under treatment B. (Cronbach & Snow, 1969, p. 4)

To increase the likelihood of obtaining a significant disordinal interaction, the relationship between the two personological variables should be low or should approach nonsignificance. Disordinal interactions exist when the regression lines for instructional treatments intersect within the range of the aptitude measure or other personological variable under investigation. This information is used to prescribe teaching treatments for students as follows: To obtain optimal student performance, learners whose aptitude measures are to the left of the intersection point of the regression lines are allotted one instructional treatment, while those whose aptitude measures are to the right of that point are allotted the other instructional treatment (Berliner & Cahen, 1973; Cronbach & Snow, 1969; Snow & Salomon, 1968). Although Glaser (1972) asserted that only disordinal interactions should be used for assigning teaching treatments to students as a function of their aptitude measures, Berliner and Cahen (1973) and Snow (1976a) proposed that ordinal as well as disordinal interactions have utility for assigning treatments to students with different aptitudes. Ordinal interactions exist when the regression lines for instructional treatments do not intersect within the range of the aptitude measure or other personological variables under investigation. Note that, to identify ordinal and disordinal interactions, consideration must be given to the correlations between student performance and aptitude and to the regression lines or slopes for different treatments.

Very few empirical data have been obtained to support the ATI idea consistently and conclusively (Berliner & Cahen, 1973; Boutwell & Barton, 1974; Bracht, Note 1, 1970; Bracht & Glass, 1968; Cronbach & Snow, 1969, 1977; Roberts, 1968-69). Bracht (Note 1, 1970) surveyed and analyzed

numerous ATI studies that (1) compared two or more alternative instructional treatments designed to attain the same educational objectives, and (2) included one or more personological variables for evaluating different treatments at distinct values of these variables. Ninety investigations were assessed for significant disordinal interactions. In these studies, 108 ATIs were scrutinized, but only five were found to have significant disordinal interactions. Of the five, just one included an educationally related personological variable; namely, under- or overachievement. Bracht drew two general conclusions from his review: (1) no available data demonstrate conclusively that personological measures of general ability and achievement are useful for discriminating among alternative instructional treatments for students within the same age range, and (2) no analyses seem to have been conducted, before studying ATI effects, of the different kinds of information processing elicited in the students by the teaching treatments themselves. Consequently, these experiments typically assessed ATI effects as an afterthought, and personological variables were not considered in an information-processing frame of reference.

Cronbach and Snow (1969) reported an extensive and systematic analysis of many of ATI's ramifications. They concluded, as Bracht did, that ATI effects are seldom established empirically; that is, significant disordinal interactions have been found and reported infrequently. They suggested that these negative results could be due to the psychometric development of the aptitude measures for selection purposes rather than for learning-performance purposes. Possibly, the instructional treatments were too poorly conceived and implemented for them to interact with learning and performance processes. Roberts (1968-69) reviewed the literature for ATI results and inferred (1) that the consequences of ATI are indeed complex, and (2) that the incorporation of practice effects makes the phenomenon even more complex. The majority of reported ATI studies have been conducted in the laboratory using artificial learning tasks, thus precluding valid generalization to the real classroom. Before such generalization can be made, more ATI investigations must be conducted using more appropriate learning materials. In most of the ATI studies surveyed, an extremely large battery of aptitude tests has been administered. Although these psychometric instruments may have had moderate reliabilities and significant correlations with performance measures, the practical use of the battery is precluded. Therefore, it seems that individualized instruction based upon aptitude tests has been restrained, since most ATI investigations have not had any important impact upon the classroom. The promises of the ATI idea have not been fulfilled; it has been almost impossible to extrapolate research results into useful adaptive instructional systems (Boutwell & Barton, 1974; Gage & Unruh, 1967). Apparently, the usefulness of the ATI construct is still to be demonstrated (Tobias, 1976).

Cronbach and Snow (1977) recently reexamined the ATI literature to gather additional evidence concerning the existence of ATIs and to identify ATI hypotheses worthy of further study. The major impetus driving investigations of ATIs has been the idea that policy decisions regarding student placement and adaptive instruction could be validly derived from established

ATI generalizations. However, the ATI literature is plagued by inconsistencies that preclude appropriate extrapolations. If there is a trend in the current literature, it would seem to be that many of the findings of ATI studies are incompatible. Consequently, it is difficult to make sound recommendations regarding adaptive instructional procedures. No ATIs have been substantiated to the extent that they can be used unequivocally as prescriptions for accommodating instruction to student characteristics. Also, the majority of ATI studies suffer from lack of replication or generalization. Although some ATIs have been empirically established, they have not been corroborated. In other investigations, either ATIs have not been demonstrated at all or the results have not been interpretable, thus emphasizing the elusiveness of ATIs.

In their latest survey, Cronbach and Snow (1977) discovered that general abilities--for example, measures of scholastic aptitude, nonverbal reasoning, and intelligence--are correlated with the rate of learning and/or the amount learned. Some ATIs were established using measures of general abilities. High general ability students thrive in instructional environments in which they can process the material to be mastered according to their own needs; low general ability students tend to perform poorly in such situations. Attempts to establish ATIs using specialized abilities--for example, spatial and mathematical abilities--have been abortive and not suggestive of useful adaptive instructional strategies. Some ATIs have employed various personality traits and styles--for example, the needs for achievement and affiliation and for constructive and defensive motivation. However, existing evidence is too scattered to allow unquestionable interpretations and confident conclusions. Contrary to what may be expected, ATI research has not demonstrated that low-ability students who use programmed instruction acquire as much knowledge as high-ability students. Likewise, few ATIs have been established that make instruction less verbal for students low in this specialized ability. Inconsistencies are readily apparent in the findings of studies that sought ATIs using selected indices of cognitive skills and structures; for example, associated memory, induction/deduction, and conceptual level. Attempts to demonstrate the existence of ATIs employing dimensions of personality such as anxiety, introversion, and motivational variables have led to the belief that these interactions (1) are very complex, being mediated by other salient student characteristics, and (2) are unlikely to be accounted for by a single generalization. Similarly conflicting results are routinely encountered regarding ATIs involving student personality variables and different learning environments and instructor styles. Consequently, no dependable extrapolations can be made for adaptive instructional purposes.

Reasons for ATI's Lack of Success

Methodological Problems

Up to now, ATI research has not discovered useful procedures to incorporate into adaptive instructional systems. One reason is that the methodology employed in many of these experiments has not been conducive

to the production of disordinal interactions (Boutwell & Barton, 1974). Only a few such methodologically sound interactions have been found to be of practical, educational utility (Berliner & Cahen, 1973; Boutwell & Barton, 1974; Bracht, 1970; Bunderson & Dunham, 1970; Cronbach & Snow, 1969; Glaser, 1972; Salomon, 1972). Not only do useful disordinal interactions occur infrequently, but they also are usually too sensitive to slight alterations in the teaching treatment, the subject matter, or the student population. Thus, methodological problems abound in ATI research. Usually, the instructional treatments have consisted of complex or uncontrolled manipulations that affect learner performance. At times it has even been difficult to distinguish among alternative teaching treatments. The aptitude and ability measures that have been used in some ATI studies have been too general and correlated to produce significant ATI effects. In some experiments, personological variables have been poorly selected; that is, they were not likely to interact with instructional treatments. In many ATI studies, the psychometric instruments employed were not appropriate for specific learning processes.

Most of the reported research on the ATI approach has employed a simple two-by-two factorial univariate ANOVA experimental design, with one factor representing instructional treatments; and the other, personological variables. It has been customary to assign alternative teaching treatments to students with distinct characteristics when significant disordinal interactions are found; that is, the differences between the two treatments at the two values of the personological variable are not only significantly nonzero, but also are dissimilar in algebraic sign. Thus, the lines representing the regressions of the treatments upon the individual difference variable intersect. This criterion, however, does not adequately protect against the possiblity of committing Type I error--rejecting the null hypothesis when it is, in fact, true. Consequently, the crossing of the treatment regression slopes is not a sufficient condition for establishing the existence of a stable ATI (Lubin, 1961; Bracht, 1970; Bracht & Glass, 1968). To further confuse the issue, some statistical techniques (Erlander & Gustavsson, 1965; Johnson & Neyman, 1936; Potthoff, 1964) that can be used for analyzing ATI studies yield dissimilar alpha levels, which reflect different probabilities of producing Type I error. Therefore, certain instructional treatments may be selected for distinct student types by using specific assignment models developed from one statistical technique but not another (Cahen & Linn, 1971).

Difficulties encountered in ATI research imply that the simplistic teaching treatment-by-personological variable factorial design may not be the proper paradigm for producing rules for adaptive purposes. Regression models may be used instead of an ANOVA for detecting ATIs. The regression techniques are much more efficient than ANOVA procedures since they tend to minimize residual error. This is partly because continuous data are typically stratified in ANOVAs, which is not the case in regression analyses. These techniques enable investigators to form interaction terms and to test them for significance. Consequently, ATIs can be efficiently created and evaluated by using regression procedures (Berliner & Cahen, 1973; Cronbach & Snow, 1977).

Important progress has been made in the development and advancement of multivariate methods for statistical analyses. Educational and psychological researchers should take advantage of these sophisticated techniques to resolve the salient issues that impede the identification and definition of prescriptive teaching paradigms. Recent advances in multivariate statistical procedures (Bock, 1975; Cattell, 1966; Draper & Smith, 1966; Kerlinger & Pedhazur, 1973; Morrison, 1967; Overall & Klett, 1972; Royce, 1973; Timm, 1975; Ward & Jennings, 1973), especially cluster analysis (Anderberg, 1973; Everitt, 1976; Hartigan, 1975; Tryon & Bailey, 1970) and multidimensional scaling (Green & Carmone, 1970; Romney, Shepard, & Nerlove, 1972; Shepard, Romney, & Nerlove, 1972; Subkoviak, 1975), enable scientists to study on a much more comprehensive basis the relationship between the student and the attributes that may have utility for adapting instructional treatments to individual differences. By employing multivariate methods, may of the impediments that result from using simple univariate ANOVA models to study ATIs may be surmounted. An example of using regression analysis techniques in this manner is the work of Rivers (1972). Some of the rationale for using such a model to adapt instruction was specified by Hansen, Brown, Merrill, Tennyson, Thomas, and Kribs (1973). Now Hansen and others are further exploring the use of regression procedures together with clustering algorithms for assigning alternative teaching treatments to students with different characteristics.

Apparently, much ATI research has proceeded on the basis of trial and error (Salomon, 1972). Some researchers (Labouvie-Vief, Levin, & Urberg, 1975) have emphasized that ATI results are so diverse that they are almost impossible to interpret and replicate. The "shotgun" approach, in which numerous personological variables are intercorrelated with slight theoretical justification, does not facilitate the straightforward interpretation of results. What is needed is a meaningful conceptual framework that can be used to generate further ATI research. A possible point of departure for establishing a speculative scheme for ATI studies is the work of Fleishman (1972) and Fredericksen (1969) on intellectual abilities and learning performance. It should be noted that conceptually personological variables of general ability and aptitude appear to have no real utility for ATI research since they are likely to predict success for several alternative instructional treatments.

Conceptual Difficulties

Boutwell and Barton (1974) have indiciated that theoretical or conceptual problems, in addition to methodological difficulties, have limited the practical payoffs from ATI research. Possibly, the implicit assumption that instructional treatments can be accommodated to students on the basis of personological variables is in error. If the correct procedure is to adapt instruction more minutely and dynamically, then many aptitude measures that have been employed for discriminating among students in static, macro instructional systems are inappropriate for finer and more continuous prescriptions. Most aptitude tests have been designed and developed to predict student performance under fixed, macro teaching treatments, and not within changing micro adaptive instructional systems.

Other conceptual difficulties have afflicted numerous ATI investigations. For example, few personological variables and alternative teaching treatments have been carefully conceived. In many studies the instructional treatments have differed only slightly, making it difficult for these treatments to interact differentially with personological measures. The alternative abilities model (Tobias, 1976) that forms a theoretical framework for ATI research has been undermined by such methods. If alternative instructional treatments are not distinct, then they probably would not require different abilities from students for optimal performance. An important restriction of the alternative abilities model for ATI investigations is that "even though different instructional methods are designed to draw on different abilities, the abilities may not be exclusive" (Tobias, 1976, p. 64).

Another distinct difficulty of the alternative abilities model is the idea that different abilities contribute more or less to performance at distinct stages of learning (Fleishman & Bartlett, 1969; Roberts, 1968-69; Tobias, 1976). The relationship between abilities and acquisition is complex since, in the course of learning, it usually fluctuates as a function of when performance data are obtained. This phenomenon further compounds the predictability of learning behavior using ability measures because the mental processes demanded by a task change with practice. Therefore, the instructional treatments designed to teach the task would have to change during training. This might prohibit the development of different teaching treatments, whereas the extent to which they require alternative abilities will probably change over the course of acquisition. The development of distinct treatments may not be practical under these circumstances since it may not be cost-effective.

A distinct issue regarding the alternative abilities ATI formulation is whether or not specific patterns of personological variables will be equally critical for teaching different content areas. If established ATIs are content-limited (Nuthall, 1968; Tallmadge & Shearer, 1969, 1971), then these interactions may have only slight practical and theoretical utility. Little can be deduced concerning useful and optimal instructional treatments from one subject matter to another when ATIs are content-specific. Restricted generality across subject matters is not conducive to speculation among researchers regarding possible ATIs in other content areas. Therefore, a subject-matter particular, alternative-abilities ATI model may be more of a task-by-instructional-treatment paradigm, with personological variables accounting for very little variance. Also, another paramount problem in ATI investigations is the possible confounding of content with teaching treatment. At times it is difficult to determine whether the reported interactions are between abilities and instructional treatments or between abilities and subject matter (Fleishman & Bartlett, 1969).

A final difficulty of the alternative abilities paradigm is that it may be impractical to design and develop distinct instructional treatments to interact with independent personological variables. A way around the many problems of the alternative abilities formulation may be

to use measures of prior academic achievement, such as pretest scores, instead of measures of abilities. The interaction of preceding levels of achievement with teaching treatments may be employed adaptively for instructional purposes. Tobias (1976) hypothesized that,

> The higher the level of prior achievement, the lower the instructional support required to accomplish instructional objectives. Conversely, as level of prior achievement decreases, the amount of instructional support required increases. (p. 57)

Irrelevant Mental Abilities and Aptitudes

The identification of individual characteristics is the essence of traditional psychometrics, which have used measures of mental abilities and aptitudes to predict student performance and achievement. Unfortunately, such tests may be better indicators of previous learning than of innate aptitude or ability. If knowledge acquired in the past can be readily altered by recent exposure to present instructional input, then the use of ability and aptitude measures to forecast achievement may simply produce a Pygmalion effect (Bloom, 1956; Packard, 1972).

Psychometrically developed predictive paradigms have had little success in prescribing instructional treatments (Cronbach & Gleser, 1965; Cronbach & Snow, 1969). This suggests that ability and aptitude tests are not useful measures of the characteristics that are likely to interact with alternative instructional treatments. Measures that have been derived psychometrically for selection purposes apparently are not pertinent to the processes of learning and performance. Neither the personological variables nor the instructional treatments employed in most reported ATI studies have been chosen as a consequence of a systematic analysis of the psychological processes mediating student learning and performance; rather, tests of general abilities and aptitudes have been produced and validated within distinct educational environments. Consequently, these instruments are important indices of instructional outcomes but are not useful indicators of optimal learning processes or instructional treatments; that is, measures of general ability and aptitude were designed to select students who would probably benefit the most from education in general. As such, these psychometric instruments cannot identify which instructional treatments are best for specific types of students. Tests of general ability, aptitude, and intelligence cannot distinguish styles of learning. Instruments of this sort are not intended (1) to appraise prerequisite performance capabilities that are necessary for mastering a new task, (2) to indicate psychological processes that mediate distinctive manners of learning, or (3) to identify the learning styles that are best for different types of students. Efforts to distinguish specific abilities or aptitudes that are pertinent to particular teaching programs are just as unlikely to be beneficial for adaptive instruction (Glaser, 1972; Tobias, 1976).

Some researchers (e.g., Fleishman, 1967; Fleishman & Bartlett, 1969) consider abilities a class of "mediating processes" that explain

consistencies in observed performance. Ability is thought of as applicable to many tasks, whereas skill is something specific and unique to the performance of a single task. This ability/skill formulation is somewhat congruent with an information processing interpretation of learning. In this framework, abilities describe various sorts of information processing (e.g., verbal, visual, proprioceptive). These can be used to conceptualize the changes that occur in the relationship between ability and performance during the practice of complex skills.

However, a word of caution is in order: Evidence seems to indicate that even pure factor psychometric instruments do not measure the identical thing in all persons. Individual differences in test taking, problem solving, and decision making have no bearing on the factorial content of a psychometric instrument. Consequently, a test is likely to measure contrasting abilities among individuals and to yield disparate patterns of correlations with other tests for distinct groups of people. Thus, factor loadings will be indeterminate and different among populations (French, 1965). Psychometric instruments that possess these characteristics should be avoided for adapting instruction to individual differences. It might be better, for this purpose, to devise and use tests that assess problem-solving and decision-making styles.

Traditional measures of general abilities and aptitudes presume too much uniformity and minimize, to some extent, individual adaptability. This has contributed to the tendency to think of people as fixed types with unchanging characteristics. That tendency has, in turn, resulted in the development of unaccommodating instructional systems and treatments. Actually, student attributes, abilities, and aptitudes vary, and this should be taken into account when designing individualized instructional systems (Glaser, 1972; Mischel, 1969). If these systems are to be responsive to changeable student characteristics, then another conceptualization of measurement and instruction is required. Student attributes must be assessed throughout instruction; it would be inappropriate simply to employ stable measures of general abilities and aptitudes. Similarly, it is insufficient to use criterion-referenced testing as opposed to norm-referenced testing without considering the changeableness of student characteristics (Seidel, 1971). Another problem is the misconception that intelligence test scores represent the ability to learn. Such thinking may contribute to the use of this characteristic in an adaptive fashion, but factor analyses have demonstrated its nonunitary nature. Also, correlations between intelligence and learning improvement have often been very low (Fleishman & Bartlett, 1969).

ALTERNATIVE APPROACHES TO ADAPTIVE INSTRUCTION

Relevant Cognitive Processes

In the last several years, interest in the cognitive processes involved in memory and learning has increased dramatically. Many recent texts and articles have emphasized the mental mechanisms mediating human performance (e.g., Anderson, Spiro, & Montague, 1977; Cermak, 1975; Estes, 1975; Kintsch, 1970, 1974; Klahr, 1976; Melton & Martin, 1972; Neisser, 1967; Newell & Simon, 1972; Norman, 1970; Paivio, 1971; Resnick, 1976; Solso, 1973; Tulving & Donaldson, 1972). At the same time, the previously distinct perspectives of educational and cognitive psychology seem to have converged. Among the reasons for this phenomenon are the following: (1) many experimental psychologists have shifted their interests from limited laboratory studies to practical educational considerations, (2) much research and theoretical interest has been generated by Jean Piaget's (1945/1951, 1936/1952) concepts of cognitive development, and (3) numerous studies reflect an increased attention to individual differences, not for discriminating among individuals but for prescribing instructional treatments as a function of cognitive characteristics (Kogan, 1971; Rigney & Towne, 1970; Seidel, 1971).

These process perspectives of learning and performance, as opposed to traditional behavioristic theories, stress the use of cognitive operations or mechanisms in acquiring or retaining knowledge. Students are perceived as processors of information input, manipulators of intellectual throughput, and producers of performance output. The operations that learners perform during these intervening stages of cognition include selecting, encoding, organizing, storing, retrieving, decoding, and generating information. These mechanisms may involve conjuring images, memorizing items, analogizing notions, rehearsing performances, and elaborating contents. Other aspects of these internal processes consist of recognizing patterns of incoming stimuli, exercising decision rules for emitting relevant responses, formulating heuristic hypotheses when appropriate judgmental paradigms are unavailable, and producing algorithms for problem solving. All of these mediating activities are largely under the voluntary and conscious control of the learner (Black, Note 2; Boutwell & Barton, 1974; Glaser, 1972; Glaser & Resnick, 1972; Melton, 1967; Rigney & Towne, 1970; Rohwer, 1970a, 1970b, 1971; Seidel, 1971; Tobias, 1976).

It is these cognitive processes that should be considered in the design and development of adaptive instructional systems. Customary measures of abilities, aptitudes, and other attributes have been produced primarily for prediction, not as tests of cognitive processes that mediate distinct types of learning and performance. Therefore, traditional psychometric measures are not indices that suggest how to support and facilitate the processes of acquiring knowledge or evoking performance. It appears that, if instruction is to be successfully accommodated to differences among learners, then mediation mechanisms or their correlates must be measured and employed to prescribe particular teaching treatments. Intervening processes used by different students to acquire, retain, and retrieve specific material must be analyzed before selecting the most appropriate instructional technique. Ascertaining the nature of this mediating cognitive activity will allow the selection of alternative teaching strategies and tactics to improve instruction.

Within this framework it is neither necessary nor sufficient to speculate about or to determine which abilities or aptitudes are related to learning and performance. In the traditional ATI orientation, it has been customary (1) to examine variations in abilities and aptitudes among students to select instructional treatments, and (2) to neglect differences in intervening cognitive activities among these same students. However, so that the entire effort is not futile, the very processes that are intrinsic to learning should be paramount considerations in adapting instructional techniques to individual differences. To take these mental mechanisms into account, it may be necessary to establish a taxonomy of dissimilar learning tasks and to determine the various cognitive mediators used by different students to master these distinct tasks. Based upon this knowledge, it should then be possible to assign instructional treatments to support students' mediational mechanisms and, thus, to facilitate the learning of different tasks. Consequently, accommodative instructional systems are designed around relevant cognitive processes, not around irrelevant mental abilities and aptitudes. In this context, the psychological processes employed by students in taking ability and aptitude tests are actually more important than the results themselves (DiVesta, 1973; French, 1965; Glaser, 1972; Rigney & Towne, 1970).

The cognitive processes used in task mastering, problem solving, and decision making should be determined, measured, and monitored. This can be facilitated by employing computer-based instructional and informational systems. Once the appropriate measurement procedures are developed, they may be applied interactively, thus making it possible to shape or support a student's mediation activity intrinsic to learning or performance. Under these circumstances it is not the subject matter that is primary, but rather the internal processes used in acquiring, retrieving, and applying this content; that is, the mental mechanisms employed in learning and performing emerge as more important than the subject matter. Consequently, when the learner encounters new tasks to be mastered, new facts to be remembered, and new rules to be acquired, he should be better able to cope with these situations by applying or transferring his mediation skills regardless of the content area. Cognitive processes should be considered in the design and development of adaptive instructional systems. If instruction is to be successfully accommodated to individual differences among learners, then mediation mechanisms must be measured and employed to prescribe particular teaching treatments. Accommodative instructional systems should be designed around relevant cognitive processes, not around irrelevant psychological abilities and aptitudes.

Cognitive Processes as Individual Differences

Some research (e.g., Coop & Sigel, 1971) has suggested that individuals differ greatly with regard to the psychological processes they use to mediate the acquisition, organization, retention, and generation of knowledge. These differences may be attributed to the adoption of learning sets that the students perceive to be pertinent to the task at hand. Therefore, the disparity among students in acquiring, retaining, and retrieving information may not be due to dissimilarities in general abilities

and aptitudes, but rather to differences in the learning sets, competencies, schemata, knowledges, and rules that the students bring into the instructional environment (Glaser, 1976a, 1976b; Rumelhart & Ortony, 1977; Scandura, 1971, 1973, 1977). This implies that, to master a primary task, the student should learn the supporting subordinate skills and the proper integration of these secondary competencies. These sustaining learning sets, schemata, skills, and knowledges are cognitive mediators that facilitate the transfer of lower-level competencies to higher-level competencies in the learning hierarchy. It should be noted that the supporting internal processes or mental mechanisms employed in the initial phases of learning will probably be quite distinct from those used in the final phases. This shift should be useful for adapting instruction to individual differences (Boutwell & Barton, 1974; Briggs, 1968; Fleishman & Bartlett, 1969; Gagne' & Paradise, 1961; Snow, 1976b).

Traditional psychometric theory, ironically, has not sufficiently considered the variability among individuals. Correlations between psychometric measures of abilities, aptitudes, and other attributes and performance indices do not provide insight into the nature of the mental mechanisms that account for these behavioral differences. However, this does not preclude the use of psychometric instruments for predictive purposes. Although psychological testing has traditionally been employed to categorize people according to taxonomies of abilities and aptitudes, it has neglected to identify the internal processes that underlie such classifications. Consequently, to account adequately for individual differences, theoretical constructs are needed that are derived from a cognitive processes frame of reference. Carroll's (1976) conceptualization of psychometric tests as cognitive tasks to produce a new structure of intellect may be a significant first step in this direction. Instead of normatively based, psychometric measures of abilities and aptitudes with static, trait-like properties, what is needed is a set of individually based, idiosyncratic indices of cognitive processes with dynamic, state-like properties. With such indices, instruction can be improved by prescribing treatments to support beneficial mediation activity or to modify detrimental, interfering mediation activity (Glaser & Resnick, 1972; Hunt & Lansman, 1975; Seidel, 1971).

Sufficient empirical evidence exists to support the thesis that intervening processes are inherent in learning and performance (Estes, 1975; Melton & Martin, 1972; Paivio, 1971; Solso, 1973; Tulving & Donaldson, 1972). It seems likely that individual variability in acquiring, retaining, and retrieving knowledge can be analyzed in terms of the processes intrinsic to this cognition. In this context, cognitive processes are considered individual difference variables that are potentially useful for adaptive instructional purposes. Seldom have variations in mediation mechanisms or psychological processes been employed to accommodate teaching procedures to differences among students. Not to examine the likelihood of using these mediational processes for adaptive instruction is to negate the very essence of individual differences in learning and performance (Boutwell & Barton, 1974; Coop & Sigel, 1971; Glaser, 1972, 1976a, 1976b; Hunt, 1976; Labouvie-Vief et al., 1975; Melton, 1976). It may be worthwhile to identify the types of cognitive processing used

by different individuals as they learn distinct tasks. This information may be used either to adapt instructional treatments to maintain mediation mechanisms or to modify the mental elaboration itself so that it is more conducive to task mastery. Individuals could even be taught the mediating processes or the elaborating techniques that contribute to learning or performing a particular task. Many different instructional treatments specific to cognitive processes are possible (Coop & Sigel, 1971; Glaser, 1972, 1976b; McKeachie, 1974; Rigney, 1976; Rohwer, 1970a, 1970b; Schroder, Driver, & Streufert, 1967; Snow & Salomon, 1968). The new aptitudes or cognitive processes can probably be modified by appropriate training to produce a useful procedure for adaptive instructional purposes. Research is required to determine whether it is better to assign instructional treatments to capitalize on potent cognitive processes, or to assign instructional treatments to improve impotent cognitive processes (Berliner & Cahen, 1973).

Cognitive Styles

Although commonalities must exist, to some extent students use their own modes of information processing to acquire, retain, and retrieve material. This implies that acquisition and performance depend upon how the learner manipulates and processes material. The ways that a student selects, encodes, organizes, stores, retrieves, decodes, and generates information are called "cognitive styles" when they affect learning and performance.

> Cognitive styles can be most directly defined as individual variation in modes of perceiving, remembering, and thinking, or as distinctive ways of apprehending, storing, transforming, and utilizing information. It may be noted that abilities also involve the foregoing properties, but a difference in emphasis should be noted: Abilities concern level of skill--the more and less of performance--whereas cognitive styles give greater weight to the manner and form of cognition. (Kogan, 1971, p. 244)

These predominant modes of information processing are presumed to be relatively stable and somewhat trait-like. In fact, cognitive styles have been considered to be the "new aptitudes." Presumably, they are acquired general tendencies and, as such, involve the transfer of predominant modes of information processing or preferred learning sets to the acquisition, retention, and retrieval of new knowledge (DiVesta, 1973; Glaser, 1972; Kagan, Moss, & Sigel, 1963; Kogan, 1971; Snow & Salomon, 1968).

Some dispute has existed regarding the differentiation of cognitive style from general ability. One line of thought says it is unlikely that cognitive style (e.g., field independence) will be distinct from general ability (e.g., verbal intelligence). A significant amount of variance seems to be common to the measures of these two psychological constructs, but this apparent commonality does not preclude the existence of some aspects of cognitive style that are separate from general ability. The other line of thought emphasizes that psychometric tests of cognitive style are independent of indices of general ability and aptitude. Consequently, information

on cognitive style complements information on general ability and aptitudes. This implies that both sets of data are important with respect to the assignment of alternative instructional treatments to students as a function of differential characteristics (Kogan, 1971; Satterly, 1976; Vernon, 1972).

Messick (1976, pp. 7-10) discussed several distinctions between cognitive styles and mental abilities:

> Cognitive styles differ from intellectual abilities in a number of ways, and contrasting them with abilities serves to illuminate their distinctive features. Ability dimensions essentially refer to the content of cognition or the question of <u>what</u>--what kind of information is being processed by what operation in what form? . . . Cognitive styles, in contrast, bear on the question of <u>how</u>--on the manner in which the behavior occurs. The concept of ability implies the measurement of capacities in terms of maximal performance, with the emphasis upon level of accomplishment; the concept of style implies the measurement of characteristic modes of operation in terms of typical performance, with the emphasis upon process. Abilities, furthermore, are generally thought of as unipolar, while cognitive styles are typically considered to be bipolar in the sense of pitting one syndrome or complex of interacting characteristics . . . against a contrasting complex at the opposite pole of the distribution. Abilities vary, then, from zero or very little to a great deal, with increasing levels implying more and more of the same facility . . . . Cognitive styles, on the other hand, range from one extreme to an opposite extreme, with each end of the dimension having different implications for cognitive functioning. . . . Conceptualizing cognitive styles has a certain typological flavor, and styles are often described as if they were types or even stereotypes, when in reality individuals are distributed continuously between the extremes with considerable variation in the cluster and degree of components comprising the style . . . . Another major way in which cognitive styles differ from abilities is in the values usually conferred upon them. Abilities are value directional: having more of an ability is better than having less. Cognitive styles are value differentiated: each pole has adaptive value in certain circumstances. The high end of ability dimensions is consistently more adaptive, whereas neither end of cognitive style dimensions is uniformly more adaptive; in the latter case adaptiveness depends upon the nature of the situation and upon the cognitive requirements of the task at hand . . . . Cognitive styles also differ from abilities in their breadth of coverage and pervasiveness of application. An ability usually delineates a basic dimension underlying a fairly limited area . . . . Cognitive styles, in contrast, cut

across domains. They appear to serve as high-level heuristics that organize lower-level strategies, operations, and propensities--often including abilities--in such complex sequential processes as problem solving and learning.

Cognitive style itself is a psychological construct that was created to indicate consistency in the manner of information processing (Messick, 1976). However, there has been some inconsistency among researchers regarding the operational definition of this abstract concept. Investigators have designed and used many different measures and methodologies to identify and define an individual's cognitive style (Kogan, 1971). Consequently, this term has been employed by a number of researchers to refer to distinctly different aspects of psychological processing. It seems, then, that the use of this construct in the literature has become highly investigator-specific, which can distress the reader.

Kogan (1970) defined several important dimensions of cognitive style:

1. Field independence vs. field dependence: an analytical, in contrast to a global, way of perceiving (which) entails a tendency to experience items as discrete from their backgrounds and reflects ability to overcome the influence of an embedding context.

2. Scanning: a dimension of individual differences in the extensiveness and intensity of attention deployment, leading to individual variations in the vividness of experience and the span of awareness.

3. Breadth of categorizing: consistent preferences for broad inclusiveness, as opposed to narrow exclusiveness, in establishing the acceptable range for specific categories.

4. Conceptualizing styles: individual differences in the tendency to categorize perceived similarities and differences among stimuli in terms of many differentiated concepts, which is a dimension called conceptual differentiation, as well as consistencies in the utilization of particular conceptualizing approaches as bases for forming concepts (such as the routine use in concept formation of thematic or functional relations among stimuli as opposed to the analysis of descriptive attributes or the inference of class membership.

5. Cognitive complexity vs. simplicity: individual differences in the tendency to construe the world, and particularly the world of social behavior, in a multidimensional and discriminating way.

6. Reflectiveness vs. impulsivity: individual consistencies in the speed with which hypotheses are selected and information processed, with impulsive subjects tending to offer the first answer that occurs to them, even though it is frequently incorrect, and reflective subjects tending to ponder various possibilities before deciding.

7. Leveling vs. sharpening: reliable individual variations tend to blur similar memories and to merge perceived objects or events with similar but not identical events recalled from previous experience. Sharpeners, at the other extreme, are less prone to confuse similar objects and, by contrast, may even judge the present to be less similar to the past than is actually the case.

8. Constricted vs. flexible control: individual differences in susceptibility to distraction and cognitive interference.

9. Tolerance for incongruous or unrealistic experiences: a dimension of differential willingness to accept perceptions at variance with conventional experience. (p. 246)

These constituents of cognitive style are typical representations of the many modes of mental processing that have been offered to account for individual differences in psychological functioning. Although a few of the terms that refer to the components of cognitive style may be unfamiliar, most of them relate to familiar, dynamic, state-like variables such as attention, expectancy, concentration, or anxiety (Coop & Sigel, 1971, Kagan & Kogan, 1970; Kahneman, 1973; Kogan, 1971).

Cognitive styles themselves seem to be mutually compatible and relatively permanent to the extent that their components appear to oppose any alteration via experimental manipulation. Consequently, a difficult dilemma arises concerning how to adapt instruction: Is it better to assign instructional treatments to capitalize on potent cognitive processes, or to assign instructional treatments to improve upon impotent cognitive processes? The latter's implication that cognitive style is changeable could produce a different orientation toward adaptation; namely, rather than accommodate alternative instructional treatments to cognitive style, accommodate cognitive style to alternative instructional treatments. This approach is probably precarious because a cognitive style that is compatible with one instructional treatment may not be compatible with another. Therefore, what would be a facilitating learning set in one teaching context may be inhibiting in another (Kogan, 1971).

This unconventional concept of the changeability of cognitive style differs from the conventional concept of the stability of general ability and aptitude. Although this unconventional concept implies that cognitive styles can be modified more than mental abilities and aptitudes, this does not preclude the possibility of altering aptitudes to adapt teaching. The possibility that new psychological aptitudes or cognitive processes

can be modified by appropriate training implies that they can be learned as well as forgotten. Used adaptively, they can be (1) employed to prescribe initial instructional strategies, (2) modified to yield sequential cognitive styles, and (3) considered for selecting terminal teaching tactics. Again, the conventional point of view emphasizes cognitive style's stability and generality, which are ascribed to their association with generalized intellectual ability. Since cognitive style is not changeable it is not trainable for adaptive instruction (Boutwell & Barton, 1974; Glaser, 1972; Glaser & Resnick, 1972; Mischel, 1969; Rigney, 1976; Witkin, Goodenough, & Karp, 1967).

Before valid and reliable generalizations can be made to the classroom, investigations should (1) consider appropriate psychological processes and (2) use relevant learning materials. Many important problems must be resolved before extrapolating and adopting a cognitive processes approach to adapting instruction; for example:

> Does the cognitive style of the individual student in a given classroom influence his learning ability? Does style determine how a student might learn best? Does style determine what a student chooses to learn? Does style interact with teaching method to produce different optimum learning situations for students with differing cognitive styles? Does the type of teaching method to which students are exposed effect any change in their cognitive styles? Can we design teaching methods to facilitate particular students with particular cognitive styles? Do different types of materials used in the presentation of stimuli to students interact with the students' cognitive style to influence the learning outcome? . . . One of the most crucial tasks for psychological researchers is that of clarifying the existing construct of cognitive style through systematic investigation. [To what degree do different constructs of cognitive style overlap?] What is the factor structure of each existing construct of style? What are the major dependent variables affected by different stylistic preferences or abilities? Such dependent variables as how learners approach various learning tasks, the ease and speed with which they finish these tasks, and the retention and organization of the information gained from these tasks would seem to be germane areas for further research. Further research also may investigate the feasibility of constructing style profiles of individual students similar to current personality profiles. These style profiles, which would incorporate a number of existing measures of cognitive style, may prove to provide more sensitive data for educators as a basis for truly individualized instructional programs. (Coop & Sigel, 1971, pp. 156-160)

Within-task Measures

It has been customary to employ pretask measures of abilities, aptitudes, and other attributes to predict learner behavior before prescribing specific teaching treatments based on individual characteristics. However, some researchers (Leherissey, O'Neil, Heinrich, & Hansen, 1973; O'Neil, Spielberger, & Hansen, 1969; Tennyson, 1975; Tennyson & Boutwell, 1973) have attempted to establish ATIs using within-task measures rather than pretask measures. It has been suggested that within-task measures of student behavior and performance--such as number of errors, response latencies, and emotive states--can be used for adaptive purposes. Such measures, taken during the course of learning, may provide for the manipulation and optimization of instructional treatments and sequences on a much more refined scale, such as varying the amount of prompting, feedback, incentives, and examples (Atkinson, 1976).

The use of micro treatments based upon within-task measures does not preclude the traditional use of macro treatments based upon pretask measures. These distinct instructional strategies should be utilized to complement one another; that is, once the optimal macro instructional treatment has been selected as a function of pretask measures, micro instructional treatments can be selected as a function of within-task measures. If course content is complex, then it is possible to design an instructional system with multiple modules and entry points. The advocated criterion for accommodating instruction, then, is the correct classification of the student's successes and failures manifested over the course of learning. This is the suggested sine qua non for optimally prescribing instructional treatments. In addition, the increased reliability of a sequence of within-task state measures as opposed to a single pretask trait measure should improve the validity of adaptive instructional decisions.

It is necessary not only to evaluate the effectiveness and efficiency of suggested adaptive instructional strategies, but also to conduct cost-benefit analyses of alternatives. The costs of individualizing instruction may be prohibitive. Also needed is a meaningful conceptual framework that can be used a priori to generate research on adaptive instruction based upon a coherent theory of cognitive processes (Labouvie-Vief et al., 1975; Salomon, 1972). It may be better to modify the best existing instructional treatment than to adapt multiple teaching strategies based upon uncertain ATI research. Bunderson and Dunham (1970) said that, instead of attempting to establish significant disordinal interactions as the basis for assigning alternative macro teaching treatments, the useful results from ATI research should be employed to establish the best instructional program for low-aptitude personnel. Micro instructional treatments could then be used adaptively in such a program.

Learner Control and Dynamic Characteristics

The identification of ATIs may be inadequate and unnecessary for individualizing instruction. Merrill (1975) systematically examined some of the assumptions implicit in the ATI approach advocated by Cronbach and Snow (1977) for adapting teaching techniques to individual differences.

In contrast to what is inherent in the ATI formulation pertaining to the permanence and pervasiveness of different individual attributes, Merrill emphasized that student performance is not affected by stable attributes, but by their dynamic characteristics. Similarly, it is not fixed, preset instructional strategies that have utility for ATIs, but transient teaching tactics. In adapting instruction, personological variables are more useful for predicting pupil performance than are measures of stable, trait aptitude.

> The search for the interaction of stable trait aptitudes and fixed treatments is never likely to be of instructional value. At the very moment one has identified such a relationship the aptitude configuration of the student has changed, never to be repeated. Hence the finding is descriptively interesting but prescriptively of little or no value. (Merrill, 1975, p. 221)

Adaptations based upon traditional ATI investigations will probably produce pupils who are dependent upon instructional systems. Rather than having teaching techniques selected for them, the students should be given the opportunity to choose their own. Learners can become system-independent if they are allowed to manipulate and accommodate treatments to their own momentary, cognitive requirements. This can be accomplished by designing a dynamically adaptable instructional system in which students actively and continuously select the instructional treatments that they feel are most appropriate. The measurement of stable, trait-like aptitudes is not a prerequisite for the implementation of this actively accommodating individualized instruction. Merrill's learner control approach to adaptive teaching is an important departure that goes beyond the ATI formulation supported by Cronbach and Snow.

Learner control may be an alternative procedure for accommodating instruction to students' dynamic characteristics, but its effectiveness depends to a large extent upon how well each student can decide which learning strategy is best for him at any one moment. Some students may not be as adept as others at selecting appropriate learning strategies for themselves or at managing their own instruction (Beard, Lorton, Searle, & Atkinson, 1973), and others may not care to do so or may feel that they are being short-changed since the teacher is not always there to guide them. Much remains to be known regarding this adaptive teaching procedure (Steinberg, 1977), especially with regard to one salient question: which student characteristics are indicators of success in this dynamic instructional environment? Research is urgently needed to identify (1) which cognitive characteristics are salient for learner control, and (2) which students can succeed in this type of dynamic instructional environment.

Although tests that measure changeable and particular characteristics may be more amenable to ATIs (Goldberg, 1972), it may be feasible to use measures of intelligence in an accommodative manner for instruction. It is not unreasonable to consider intelligence to be as changeable as motivational, emotional, and physiological states, although this is contrary to the traditional belief that psychometric indices of intelligence are

relatively stable. Changes in intelligence have typically been attributed to errors of measurement, but data have shown that intelligence has variable and state-like characteristics. Short-term changes in intelligence have been observed in the form of consistent fluctuations in convergent and analogic-semantic reasoning and figural reasoning, thus implying that these changes may characterize intelligence in general (Horn, 1972). Consequently, if intelligence has stated as well as trait attributes, then it may be appropriate for use in a truly adaptive instructional system. Similarly, the distinction between fluid and crystalized intelligence (Cattell, 1963) may have some utility for producing significant disordinal ATIs.

Other aspects of psychometric measures also may be used for individualized instruction. For example, during the administration of a psychometric instrument, the importance of sampled abilities may shift substantially. This is especially apparent in prolonged practice on psychomotor and printed tests where factor structure and salience change over distinct phases (Fleishman & Hempel, 1954). Alterations in factor pattern and prominence with practice underscore the primacy of establishing which abilities account for the variance at separate stages on a test. Presumably, this would maximize the predictive power of psychometric instruments for adapting instruction. Knowing which abilities contribute to individual differences at earlier and later phases of performance may be useful for prescribing instructional treatments over the course of learning.

Adaptive Incentive and Feedback Techniques

Investigations of individualized instruction usually fail to examine student motivation. As Seidel (1971, p. 41) asserted, "you can lead a student to material but you can't make him think--or attend or learn." To complement the cognitive processes approach to adaptive instruction, incentive techniques, contingency-management procedures, behavior-modification principles, and other motivational schemes (Ayllon & Azrin, 1968; Bandura, 1969; Homme, 1966; Keller & Ribes-Inesta, 1974; Premack, 1965; Weiner, 1974) should be implemented and evaluated to assess the feasibility of using them accommodatively. Individualized incentives that will interact with cognitive styles, instructional treatments, and material to enhance learning and performance should be identified, as should the incentives, contingencies, and rewards that are most effective for particular types of students.

Similarly, specific feedback procedures (Adams, 1968; Bilodeau, 1966; Bourne, 1966; Kulhavy, 1976; Renner, 1965) should be selected for different types of students, subject matters, and tasks. A series of studies should be conducted to determine the effects of manipulating the availability, complexity, delay, magnitude, frequency, and timing of information feedback upon the acquisition, retention, and performance of different tasks for distinct types of students. The results of these experiments can then be employed to adapt feedback to students with different characteristics in cognitive style, confidence, and elaboration strategy. By using individualized feedback techniques that are more suited to cognitive processing during the acquisition and mastery of different tasks, the acquisition, retention, and retrieval of knowledges and skills should be facilitated.

Psychophysiological Procedures

> Currently there are two methods used to assess the electrical activity of the brain. The first consists of amplitude, symmetry, morphology, and frequency measurements of the spontaneous electroencephalographic activity (EEG) recorded from various brain regions. The second consists of evaluation of the amplitude, symmetry, and morphology of time-locked electrical oscillations, or average evoked potentials (AEP), which are elicited by the presentation of specific stimuli modalities. (Thatcher, 1976, p. 43)

Lateral hemispheric specialization of the brain has been employed as a physiological indicator of two different modes of cognitive style (Doyle, Ornstein, & Galin, 1974; Galin, 1975; Galin & Ellis, 1975; Galin & Ornstein, 1972): A verbal, analytic, sequential, and syllogistic mode of information processing has been associated with left-hemisphere activity for most right-handed individuals; and a spatial, synthetic, simultaneous, and intuitive mode, with right-hemisphere activity. Similarly, cognitive style has been related to patterns of EEG lateral asymmetry: Typically, for people performing verbal-analytic tasks, there is usually an increase in alpha waves or idling rhythm over the right hemisphere; on spatial-synthetic tasks, there is usually an increase in alpha wave or idling rhythm over the left hemisphere. The presence of the alpha or idling rhythm is an index of the diminution of information processing within that hemisphere. Some individuals predominantly employ the verbal-analytic cognitive style for problem solving and decision making, whereas others predominantly employ the spatial-synthetic cognitive style for such tasks. Individual differences in cognitive style have also been related to reflective eye movements (Galin & Ornstein, 1974): When individuals are asked a question demanding a certain amount of reflection, they usually avert their eyes briefly before answering, and it has been suggested that direction of gaze may indicate the major mode of information processing. Right-eye movements may index a greater activation of the left hemisphere; left-eye movements, of the right hemisphere.

A student's difficulty in mastering certain material or in performing a particular task may be due to his inability to adopt the appropriate mode of information processing. Since EEG and reflective-eye-movement data may provide useful procedures for assessing preferred cognitive styles, it may therefore be possible to ascertain which information processing modes facilitate the learning and performing of a task, and which modes interfere. It may be feasible to train students whose predominant cognitive style is verbal-analytic to adopt a spatial-synthetic orientation when appropriate, and vice versa. For example, biofeedback techniques could be used to instruct individuals to adopt the proper information processing mode to facilitate the learning and performing of a specific task. Alternatively, instructional strategies themselves could be adapted to conform to a learner's preferred cognitive style; that is, initial learning and subsequent performance could probably be enhanced by presenting material in the medium that is most congruent with a student's major mode of information processing. For verbal-analytical individuals, acquisition,

retention, and retrieval may be facilitated by employing a primarily verbal medium. For spatial-analytically inclined individuals, those same functions may be facilitated by employing a primarily visual medium.

> In contrast to the spontaneous EEG, the evoked potential provides several advantages in the study of human memory. The spontaneous EEG reflects at any given moment a myriad of processes, only a few of which may be related to information processing. For example, nonspecific factors such as attention, arousal, emotion, motivation, and background equilibrium changes interfere with the detection of information-retrieval processes. The evoked potential, on the other hand, allows for the synchronization of neural activity by a stimulus bearing task-relevant information. Thus, the 'signal-to-noise' ratio can be enhanced, and neural activity time-locked to the momentary presentation of an information-bearing stimulus can be isolated from non-time-locked activity. (Thatcher, 1976, p. 65)

The results that have been gained by using averaged evoked potentials' sophisticated computer-aided techniques have led researchers to conceptualize cerebral activity during learning and memory as more than simply localized to specific regions of the brain. Instead of the place analogue of human information processing, which is implied in the lateral hemispheric specialization of the cortex, several investigators (Bartlett & John, 1973; John, 1972, 1975; John, Bartlett, Shimokochi, & Kleinman, 1973; John & Thatcher, 1976; Thatcher, 1976; Thatcher & April, 1976; Thatcher & John, 1975) have hypothesized that all cortical structures are equipotential for any specific function. However, these sites vary according to their own "signal-to-noise" ratios for each specialized action.

In this context, "noise" signifies the random electrical activity of a cerebral neuron, and "signal" signifies the synchronous electrical activity of a cerebral neuron firing in rhythm with other functionally similar neurons. Practically every region of the brain contributes to many different functions, but the greater the signal-to-noise ratio of a particular region, the more that area is involved in a particular action. Structures traditionally thought to control a specialized function are actually those with the highest signal-to-noise ratio for that activity. This speculation regarding brain activity has been referred to as statistical configuration theory. According to this theory, it is not the localization of excitability that matters (e.g., left versus right idling cerebral hemisphere), but rather the rhythm of activity of one area relative to another; that is, various regions of the brain combine statistically to produce cognitive output. The rhythm of their average firing rate determines the nature of the cognitive function. Even memory for a certain event or fact is physiologically encoded as a frequency-specific activity of the entire brain rather than being mapped on a particular region.

Research should be conducted to determine the feasibility of using this equipotential model for suggesting alternative teaching strategies. Possibly, instructional treatments could be accommodated to conform to a

learner's preferred mode of information processing as specified by computer-based average evoked potential techniques. The equipotential paradigm of cerebral function, together with the necessary advanced technology, could be employed to adapt instruction to the dynamic state variables of different students. In a computer-based, individualized, and interactive instructional environment, physiological indicators could be monitored within-task to permit a more refined manipulation of teaching treatments. Within-task indicators, as well as pretask psychobiological parameters, should be more objective and unbiased indices of cognitive processing than are traditional psychometric tests of abilities and aptitudes. Some evidence has already demonstrated the improved validity of psychobiological variables over aptitude measures for predicting subsequent performance (Lewis, Rimland, & Callaway, 1976, 1977). Consequently, the aforementioned physiological correlates of human learning and memory may be more relevant for assigning alternative instructional treatments than are customary psychometric measures.

CONCLUSIONS

1. Students vary widely with regard to the psychological processes they employ to acquire, retain, and retrieve knowledge. This disparity may not be due to dissimilarities in general abilities and aptitudes, but rather to differences in the learning sets, competencies, schemata, knowledges, and rules that the students bring into the instructional environment. In this context, cognitive processes could be regarded as individual differences variables for use in adaptive instruction. However, a difficult dilemma that must be resolved is whether it is better to assign instructional treatments to capitalize on potent cognitive processes, or to assign instructional treatments to improve upon impotent ones.

2. Process perspectives of learning and performance, as opposed to traditional behavioristic theories, stress the use of mental mediators or mechanisms in acquiring and retaining knowledge. Students are perceived as processors of information input, manipulators of intellectual throughput, and producers of performance output. The operations that students perform during these stages of cognition include selecting, encoding, organizing, storing, retrieving, decoding, and generating information, all of which are potentially profitable areas of study in the design and development of adaptive instructional systems.

3. It has been customary to employ pretask measures of abilities, aptitudes, and other attributes to predict behavior during instruction. However, within-task measures of student behavior and performance during instruction (e.g., number of errors, response latencies, emotive states) are also potentially useful for adaptive teaching purposes.

4. It is not just stable student attributes that affect performance, but also their dynamic characteristics. Similarly, it is not just fixed, preset instructional strategies that have utility for ATIs, but also flexible teaching tactics. Therefore, in adapting instruction to individual differences it may be better to assume that dynamic, state, personological variables are more useful for predicting pupil performance than are stable, trait, aptitude measures.

5. Incentive techniques, contingency-management procedures, and other motivational schemes need to be evaluated to assess the feasibility of their use in an accommodative manner. Individualized incentives that will interact with cognitive styles, instructional treatments, and material to further enhance learning and performance need to be identified.

6. Information feedback procedures need to be evaluated on the basis of their suitability for specific students, subject matters, and tasks. The acquisition, retention, and retrieval of knowledges and skills may be enhanced by choosing and using the feedback techniques that are most appropriate for student cognitive processing during the acquisition and mastery of different tasks.

7. Lateral hemispheric specialization of the brain has been employed as one physiological indicator of different modes of cognitive style. However, a new conceptual model of the brain proposes that localized regions

do not participate in an all-or-none fashion in cognitive activity, but rather, various regions combine statistically to produce cognitive output. The feasibility of using both models needs to be determined for suggesting alternative teaching strategies; that is, instructional treatments can be accommodated to a learner's preferred mode of information processing as specified by computer-based, electrophysiological indices.

RECOMMENDATIONS

To maximize the cost-effectiveness of Navy technical training, several alternative approaches to computer-managed adaptive instruction should be experimentally evaluated:

1. Analyze and assess individual differences in acquiring, retaining, and retrieving knowledge.

2. Adapt instructional treatments to a student's cognitive style or predominant mode of information processing.

3. Design and develop adaptive instructional systems around the relevant cognitive processes.

4. Accommodate instruction to students using (a) micro treatments based upon within-task measures taken during the course of learning and (b) macro treatments based upon pretask measures.

5. Design and evaluate a dynamically adaptable instructional system in which students select and control the instructional treatments that they think are most appropriate to their individual needs.

6. Identify and assess adaptive incentive and feedback techniques that can be accommodated to individual students to enhance their learning and performance.

7. Select and evaluate information feedback procedures on the basis of their suitability for specific students, subject matters, and tasks.

8. Determine the feasibility of using psychophysiological correlates of cognitive processing, such as lateral hemispheric specialization, to suggest adaptive instructional strategies.

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